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Effects of Audible Human Disturbance on Koala (Phascolarctos cinereus) Behavior in Queensland, Australia and Implications for Management

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Abstract

As the growing human population continues to encroach on wildlife habitat, species are forced to adapt in order to survive. In addition to causing habitat loss, human presence can create more subtle disturbances, such as noise pollution, that disrupt wildlife behavior. Adapting to human presence is particularly difficult for species with specialized resource needs or low mobility. The koala (*Phascolarctos cinereus*), a national icon of Australia, meets both these criteria. Koalas were once abundant throughout Australia, but are now classified as "threatened." Habitat loss is at least partly responsible for this decline, but anthropogenic noise may also be a factor. The purpose of my study was to examine koala behavior in response to noise disturbance in two sites: an area of high human density and a national park. I used a logistic regression to compare behavioral responses to two types of disturbances, human-induced and natural (non-human), in both sites. The probability of a koala responding to a human disturbance was twice as great in the densely populated site (0.55) as it was in the natural park (0.27). These results demonstrate that regular exposure to human activity can actually hypersensitize wild animals to human disturbances, rather than desensitize them. Broadly, this study shows how a change in wildlife behavior can give insight into anthropogenic effects on a population. This type of information can help conservation biologists prevent further population declines.

Introduction

As the earth's population grows and urbanization increases, more wildlife are forced to interact with humans in order to survive. Human development can cause many disturbances to natural populations, whether it is in the form of deforestation, vehicle collisions, or noise from development. Habitat destruction is obviously detrimental to wildlife, but smaller interactions such as someone camping could also adversely affect wildlife, as they could be seen as a potential predator. It's been seen throughout history that where there is human development, there is species die off. Understanding how an animal reacts to development could play a key role in its conservation.

As a senior Biomedical Science: Medical and Veterinary Science major in the Pre-Veterinary program, it's no secret that I have a love for animals. I take every opportunity I can to work with animals, whether it be through an internship at a zoo or at a veterinary clinic. As a child I was enthralled by Animal Planet's "The Crocodile Hunter," where the host Steve Irwin ventured into the Australian wilderness to seek out rare and dangerous creatures in order to educate the public. It was a dream to do what he did for a living, and though I have always strived to be a veterinarian, I didn't think going on adventures like he did was possible. When I learned about the Summer Undergraduate Research Fellowship (SURF) Abroad program at UNH, it hit me: it was possible for me to go on the adventure of a lifetime, while preparing for a future in veterinary medicine where I could venture into the wilderness as part of my job. With the grant and 13 weeks in Australia, I was able to accomplish my goal of doing valuable research on a declining species, and experience something that not many are lucky enough to have the opportunity to experience.

So why should we care about koalas? This species can serve as a model for single-species conservation, or focusing on a single species rather than a whole ecosystem to conserve it. The information gained from research on conservation of the koala can be extrapolated to other species, and in other countries. The koala is the national icon of Australia, and is considered "cute and cuddly" to the general public. These details help the koalas to have ample funding for their conservation, due to public concern. They are a flagship species, and so the public donates more to the conservation efforts of it, rather than say an endangered insect. If funding is more accessible for research and conservation of a certain species, it should be used to the fullest.

Review of Literature

There are many factors that go into monitoring the effects of disturbance on a species. First of all, there are many different kinds of disturbances. For example, a disturbance could be a low-flying airplane, a gunshot, a pedestrian, or road traffic. Disturbances also affect different species in various ways. A study done on Mountain Sheep in Canada found that road traffic affected their behavior minimally, while they were greatly affected by pedestrians and dogs (Macarthur *et al.* 1982). Human disturbance has been found to affect breeding success. Snowy Plovers in California were found to have increased chick mortality when there was greater human activity on beaches (Ruhlen *et al.* 2003). Human activity can affect behavior of a species by increasing its awareness of its surroundings, as well as its stress levels. It was found that Brent Geese in the UK were very much affected by human activity such as gunshots; when exposed to these disturbances their feeding times decreased, and their vigilance and energy expenditure increased (Riddington *et al.* 2010). This increased vigilance and desire to avoid human activity, though it increases their energy expenditure, could help the species since they would avoid harmful disturbances such as hunting.

In contrast, some species aren't at all affected by human activity. Schaller, 1963, and Fossey, 1986 both found that mountain gorillas habituated to observers well in a relatively short time. Magellanic Penguins were found to habituate to tourists as quickly as within a couple of days (Walker *et al.* 2005). If a species' behavior is not at all affected by human activity, they may not try to be aware of or avoid it, which could lead to death by collisions with vehicles, confrontations with dogs, etc. Many studies have been done to show how behavioral changes due to human activity have a negative effect on a species, but there is new thought being given to the theory that lack of behavioral change may do as much damage to a species' survival, if not more.

A study was done in Florida on how human disturbances, specifically hunting, affects the behavior of White-Tailed Deer and how that in turn affects the Florida Panther, its natural predator. It was found that during hunting season, deer moved away from roads and increased their nocturnal activity. This behavior change was found to be beneficial to the endangered Florida panther, because the increased nocturnal activity and avoidance of roads in White-Tailed deer increased prey availability for the panther. It was also found to be beneficial to the panther because the deer's movement away from roads may in turn draw panthers away from roads, therefore decreasing their chance of collisions with vehicles or encounters with poachers (Kilgo *et al.* 2008). Nisbet, 2000 challenged the idea that alterations in seabird behavior due to human disturbance had an adverse effect on the species. He suggested that colonies should be managed for research, education, and recreation, rather than to be all together avoided. In this way, the public can be educated and involved in conservation management.

The koala (*Phascolarctos Cinereus*) is a national icon of Australia, beloved by natives and visitors alike. It is known worldwide, not only as a symbol of Australia, but as an example of some of Earth's unique wildlife. Once abundant in all areas of Australia when the first aboriginal people arrived, the koala is now a species "in serious trouble" (Flint and Melzer 2013). The Australian Federal Government added the koala to the threatened species list in 2012 and classified them as "vulnerable." However, this classification is most likely not enough to prevent further decline in koala populations. The Australian Koala Foundation stated that this protection does not go far enough, and that the Australian Government has underestimated the amount of danger that koalas are in (ABC Science 2012). Over the past 20 years, koala population numbers have dropped 40% in Queensland and by a third in New South Wales (ABC Science 2012). The koala conservation problem is a complicated one, as populations are thriving in South Australia and Victoria, but dramatically declining in Queensland and New South Wales. In order to compensate for this issue, and to be prioritized for conservation efforts, a classification of at least "endangered" will be needed[1] (Flint and Melzer 2013).

The three major causes of mortality in koalas are vehicles, domestic dogs, and disease (Flint and Melzer 2013). This demonstrates how human activity is affecting koala populations, since two out of the three main causes of mortality are human-based. In 1995, the Queensland Parks and Wildlife Service, the Queensland Department of Main Roads and Redland Shire Council initiated the Koala Speed Zone Trial in the Koala Coast, southeast Queensland. This study found that between 1995 and 1999, 1407 koalas were hit by vehicles in the Koala Coast, a mean of 281 koalas per year (Dique *et al.* 2003). Sadly, 83% of those hit died, 61% of which were healthy young males (2-4 years old). Males disperse more often than females in search of mates, and this large amount of death in breeding-age males is likely to negatively impact the species' population numbers (Dique *et al.* 2003). In 1997 the number of koalas hit peaked at 315, and then decreased to 252 in 1999, a worrying decline, as it may reflect a sustained reduction in the population (Dique *et al.* 2003). Trying to conserve what's left of koala populations in an ever-developing world has proven to be a difficult task, but understanding what koalas respond and react to could help conservationists learn how effectively aid the species. Do they practice avoidance behavior when it comes to vehicles like the White-Tailed deer? Or instead are they not affected by human disturbances, and is this leading them to not change their traveling behavior and run into issues when crossing roads?

[1] A taxon is Endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future, as defined by any of the criteria (A to E) as described below (IUCN 2014).

Related Studies in Other Species

In Alberta, Canada a study was done on mountain sheep and their behavioral and heart rate responses to human disturbances. They found that effects from road traffic were minimal; only 8.8% of interactions caused responses in heart rate. The interaction that caused the largest response in heart rate and behavior was human approach, particularly down a hill towards the animal, or when accompanied by a dog (Macarthur *et al*. 1982).

In Russia, a study was done on human disturbances on Amur tigers, mainly focusing on roads. It was found that in areas where there was minimal or no road access, the survival rates of cubs and adults was significantly higher than in areas where there was primary or secondary road access. Primary roads were defined as roads that were maintained year round and provided access between towns and villages. Secondary roads were defined as roads that were not regularly maintained, but provided public access into forested lands. They also found that when disturbed by human interaction, 63% of tigers abandoned their kills, leaving most uneaten. It was recommended in conclusion that roads should not be built in areas that are managed for tigers, and access to secondary roads should be reduced (Kerley *et al.* 2002).

Mountain gazelle in Israel were observed to see how human disturbance and habitat fragmentation affected social structure and behavior of a population. It was found that in disturbed areas, group size was smaller than in undisturbed areas. They concluded that human presence affects the social structure of a species, which in turn affects its evolution and population performance. This is because social structure is a key component in the evolutionary dynamics of a social species. It was recommended that human presence should be considered when managing a species in a fragmented landscape (Manor and Saltz 2003).

Researchers in California looked at Snowy Plovers and how chick survival was affected by increased human activity. It was found that on weekends and holidays, where human activity on the beaches was greater, chick survival decreased significantly. This suggested that human activity negatively affected the Snowy Plover population (Ruhlen *et al.* 2003).

In the UK, it was found that human disturbance affected the energy use and behavior of Brent Geese. The most frequent disturbance was from pedestrians, but the interaction that resulted in the most energy use was mechanized human disturbance such as gunfire or aircrafts. It was found that in response to increased disturbance, the hourly energy expenditure of geese increased, their time feeding decreased, and their vigilance increased (Riddington *et al*. 2010).

Stress in response to human disturbance was studied by monitoring stomach temperatures in Emperor Penguins in Antarctica. There was a positive correlation between stomach temperature and the intensity of the human disturbance. The increased stomach temperature due to increased stress in the penguin meant an increase in energy expenditure, and an increase in metabolic rate (Regel and Pütz 1997).

A study was done on Tufted Puffins on the Barren Islands in Alaska. It looked at the effects of human disturbance on their breeding success. Three nesting areas were monitored with differing levels of disturbance created by the researchers, such as egg handling (taking measurements, etc.). Breeding success was significantly lower in the area that was most disturbed by the researchers, as compared to the areas that were less disturbed. The chicks in the more disturbed areas hatched earlier and were less developed than in the less disturbed nesting area (Pierce and Simons 1986).

One study looked at generalized effects of road systems on an ecological community. The effects were identified as the seven following: "mortality from road construction, mortality from collision with vehicles, modification of animal behavior, alteration of the physical environment, alteration of the chemical environment, spread of exotics, and increased use of areas by humans." It was noted that road construction and traffic was more likely to kill slow-moving animals. It was recommended that construction of roads in natural areas was to be avoided and that existing roads in natural areas should either be removed or restored as to not adversely affect wildlife, such as by adding a wildlife bridge (Trombulak and Frissell 2001).

Bottlenose Dolphins in New Zealand were observed to see how ecotourism, specifically dolphin-watching boats, affects their behavior. It was shown that the dolphins decreased their resting behavior and increased their milling behavior with an increased number of boats, especially when the boats were permitted dolphin-watching boats. This was because the permitted dolphin-watching boats spent more time with the dolphins than non-permitted boats (Constantine 2004).

A study in Canada analyzed whether landscape was related to road crossings, and consequently road kill, by reptiles. It was found that more road crossings occurred in more rural areas, and areas that contained more wetlands. It was also noted that reptiles are more susceptible to road kill due to their slow movements, and the heat that the road gives off (MacKinnon *et al.* 2005).

Methods Used in Similar Studies

In the study of Mountain Sheep in Canada, heart rate telemetry was used to measure behavioral changes and stress in the animal in response to human activity. Behavior was also observed visually, and it was noted that some stress, as detected by a change in heart rate, could not have been detected by observation alone (Macarthur *et al*. 1982). In the Emperor penguin study in Antarctica, chicks were caught and induced to swallow stomach temperature monitors. The temperatures were recorded as well as their behavior, as indicator of stress. In the Tufted Puffin study in Alaska, growth data as well as physical observations were taken, since they measured the eggs and hatchlings. Both physical and physiological effects were monitored in these studies (Regel and Pütz 1997).

In the study of Amur Tigers in Russia, the tigers had been radio-collared, and were monitored and tracked either on foot or by helicopter (Kerley *et al.* 2002). In the UK study of Brent Geese, physical behavior was defined into categories such as preening or roosting, and visually monitored (Riddington *et al.* 2010). In the study of Bottlenose Dolphins in New Zealand, behaviors were defined and visually observed (Constantine 2004). In the study of deer and panthers in Florida, some of the deer were captured, radio-collared, then monitored regularly according to their movements (Kilgo *et al.* 2008). In the study on road kill of reptiles, visual observations were used to record kills, and GPS and GIS were used to map landscape and location around them (MacKinnon *et al.* 2005). Only physical effects were monitored in these studies.

Methods Used in Koala Studies

In a study of activity cycles in captive koalas at the Taronga Zoo in Sydney, cameras were set up in the enclosure, and infrared lights were used so that the animals could be observed 24 hours a day without being disturbed. The videotapes were analyzed visually, and behaviors were defined as: inactivity, feeding, change of location where the animal is not feeding and does not exceed twice the animal's body lengths, change of location where the movement is more than twice the animal's body lengths but the duration is less than three minutes per interval, and change of location where the duration is more than three minutes per interval. Grooming was categorized as inactivity and social interactions and exploratory behavior were usually combined with locomotion and so were incorporated into one of the locomotion categories. The male koala was analyzed separately to account for possible sex differences. The length of the feeding bouts was also recorded.

In the study of free-ranging koalas on Kangaroo Island (Carney and Paton), time budget data were collected by observing ten individually tagged and radio-collared koalas for 24 hour periods, and recording times when behavior changed, to the nearest ten second interval, so that duration and percentage of time spent on each activity could be calculated. Five behaviors were recorded: feeding, moving (either within a tree or from one tree to another), grooming, resting (either asleep or sitting and alert), and social interaction, such as direct contact and vocalizations.

The type of plant material consumed while feeding was also recorded (e.g. buds, fruit, and flush growth or mature leaves). The position of a koala in a tree was also recorded by estimating the koala's height in the tree using a clinometer, and by the aspect (side of tree occupied) and type of branch it was sitting on based on branching patterns of the tree. For example, primary branches were considered to be the first set of branches extending from the main trunk, secondary were those extending from the primary branches, and so on. 75 watt hand-held spotlights were used to observe the koalas at night, and red filters were attached to minimize any potential disturbance. They were also adjusted to produce the minimum intensity of light required. All observations were made from distances of at least 20 meters. Data were collected for continuous 24 hour periods by two groups of observers working in six-hour shifts. In all, ten individual koalas were observed for a total of 34 days. They ranged in size and sex. Time budgets and daily cycles of activity were extracted from the 24 hour records of activity. A bout of feeding was considered to be any period of feeding which was not interrupted for longer than five minutes by another behavior.

In a study of how tooth-wear can affect the activity cycles of free-ranging koalas (Logan and Sanson 2002), six koalas with varying degrees of tooth wear were looked at. Acoustically sensitive radio telemetry was used to detect movement and feeding patterns of the individuals. Each koala was captured and fitted with a transmitter collar, and their dentition was examined. The collar transmitted a frequency that was recorded onto videocassette tapes. The tapes were then replayed in real time and the defined behaviors were recorded.

A recent study done on activity patterns in free-ranging koalas (Ryan *et al*. 2013) addressed the problem of traditional field techniques when it came to observations of activity by using accelerometry to gain more data with less time consumption. Individuals were captured and fitted with VHF radio collars, which accelerometer data loggers were then attached to. Each koala was located with GPS at least twice a day, over a period of 7 days. The sample size was 12, then 15 koalas. Two accelerometer data loggers were also placed in a randomly selected tree to determine the effect of branches moving in the wind on the data. A visual observational study of 16 randomly selected koalas was also conducted as a reassurance that the accelerometer data were accurate.

Descriptions of Koala Behavior

The following descriptions of koala behavior were observed in and described from the koalas at Lone Pine Sanctuary, Brisbane. The koalas were completely tame, able to be handled, and it was noted that they were not disturbed by observation (Smith 1979, 1980).

Non-social behavior was defined as resting or feeding. For feeding, it was observed that they fed sporadically throughout the day, and they always seemed to feed in the same fashion: by grasping a branch, pulling it forward and biting off a leaf at its base. It was observed that they only urinate once or twice a day, always when moving, and they defecate while resting. They groom with their foot, hand, or mouth, but seem disinterested in it. They rest for 19 or more hours a day, in a vertical posture with the weight on the sacral region. They sometimes sleep in clusters but often they are alone. When in the trees, their body weight is always suspended by their arms, while on the ground they walk on all fours (Smith 1979, 1980).

Vocalizations were classified as another behavior, and there are different types. The squeak is the basic call of cubs, the squawk is a sign of mild distress or aggression the low grunt is the response to very weak stimulus contrast, and the harsh grunt is of males fighting. The snarl, wail, and scream are all agonistic calls made by females, and serve as defensive threats only. The bellow is the characteristic male call, and consists of a long series of deep, snoring inhalations and belching exhalations. It's most frequent during mating season. Females bellow less often and more softly (Smith 1979, 1980).

Scent-marking is another behavior displayed by male koalas. Males scent-mark by grasping a vertical object, usually a tree, and rubbing their sternal gland against it. It is usually performed in conjunction with bellowing, especially in response to a rival male. Scent-marking could be a response to either aggression or unfamiliarity (Smith 1979, 1980).

Aggression was also defined into a few categories. All aggressive behavior was a variation on the single motor pattern of throwing a foreleg around an opponent and biting. Squabbles were the most common aggressive behavior and were brief, low level interactions usually arising from the efforts of one koala to climb past or over another. Minor fights only involved single bites and the koalas involved did not move. Major fights involved multiple bites and changes of position (Smith 1979, 1980).

Methods

As mentioned earlier, behavior can play a key role in understanding a species, whether it be with mate selection, home range, or the health of their population. Over the course of my time in Australia, I had three study sites: the Rockhampton Zoo, St. Bee's Island, and Mount Byron. Each site differed in the level of human disturbance experienced by an animal. The Rockhampton Zoo was the most disturbed area, with visitors present every day, making large amounts of noise. Three koalas, two females and one male, were observed for this study. Mount Byron was the next level down when it came to disturbance. It was a rural site with dirt roads, but koalas were subject to daily interaction with vehicles and people due to the numerous beef cattle farms in the area. St. Bee's Island served as the site with the least disturbance. Located about 9 kilometers off of the coast of Mackay, Queensland, and uninhabited, koalas at this site experience little to no human disturbance. By doing observations in three different levels of disturbance, the effects of human disturbance on their behavior can be more clearly shown.

However, due to many factors that could skew my data such as a lack of diversity in the koalas (there were only 3), the Rockhampton Zoo was excluded from my study data. Mount Byron served as the disturbed area, while St. Bee's Island served as the undisturbed area.

At both research sites, I was accompanied by my mentor, Dr. Melzer. Upon arrival at the sites, he familiarized me with any safety hazards present and advised me on how to navigate through the area. Often other researchers were present working on their projects. For example, at St. Bee's Island there were workers from the National Parks department with us for a few days, taking vegetation samples. Both sites were populated by koalas that had been radio-collared previously by researchers from the University of Queensland. Not all of the koalas at these sites were collared, but there were enough to be able to easily find a new animal each day. Dr. Melzer taught me how to use the radio-tracking equipment before arriving at the research site. The researchers provided me with the frequencies that each koala's collar transmitted on. At the research site, I entered the list of frequencies into my radio receiver, and then searched for each one individually by walking around holding the antenna and listening for audible responses.

At Mount Byron, I stayed at the Hollow Log Country Retreat, a small cabin on a farm with Dr. Melzer and several other field biologists. I spent a collective 10 days at this site, spanned across 2 trips. When working at St. Bee's Island we stayed on a neighboring island, since St. Bee's is protected and does not have camping areas. I stayed there for 10 days. On St. Bee's, the radio-tracking equipment died on the first day, so I had to track koalas without the equipment. Dr. Melzer assisted me with this: we searched using the scratch-marks the koalas left on trees and their feces.

Figure 1: Site A is the Rockhampton Zoo, Site B is Mount Byron, and Site C is St. Bee's Island (Map credit: Google Earth)

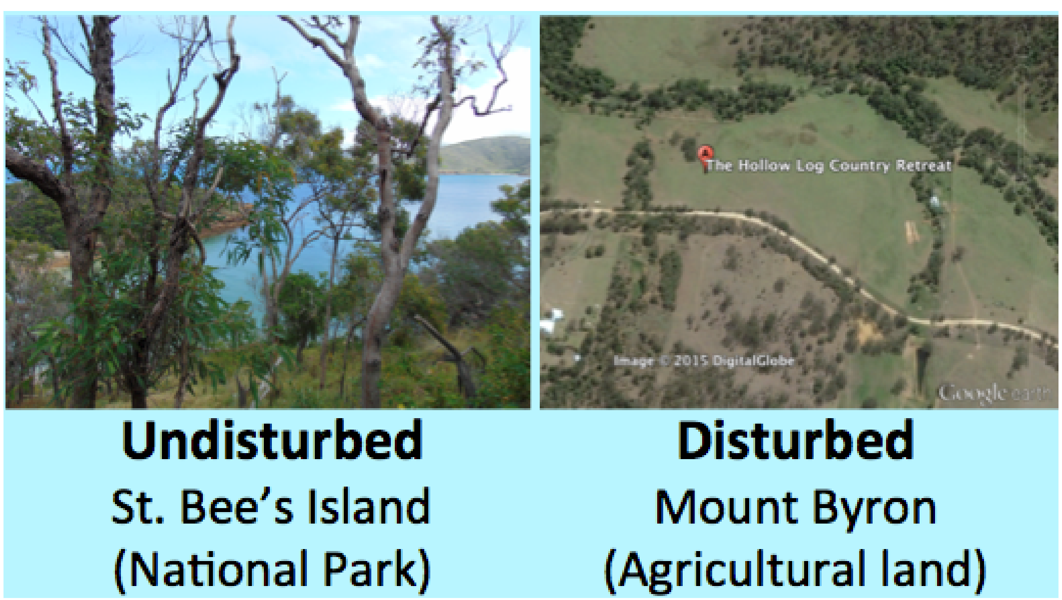

Figure 2: A picture of St. Bee's Island from the ground, and an aerial photograph of Mount Byron demonstrating the fragmented forest.

The first step was to find a koala for observation. At Mount Byron, I used radio-tracking equipment in order to locate them. Some koalas in the area had been radio-collared for a previous study, and I was given the frequencies that each individual transmitted on. I could then input these frequencies into the receiver and search using an antenna. This method was also to be used at St. Bee's Island, but upon arrival to Keswick Island (adjacent to St. Bee's Island, where we were staying) my mentor discovered that the receiver was not working. So, during my ten days on St. Bee's Island, I had to track koalas the old-fashioned way, with the help of my mentor. We walked slowly throughout the forests, taking note of fresh droppings and scratch marks on trees left by climbing koalas. It was time consuming, but we were usually able to find a koala within an hour each day.

Figure 3: Holding an antenna to search for koalas

Figure 4: A radio collar that had fallen off a koala.

Figure 5: A radio-collared koala.

Once I found a koala, I was sure to find a spot to sit where it could not see me, and I sat quietly enough so that it could not hear me. I waited 15 minutes after I sat down to start the observations in order to allow the koala to acclimate to my presence if it had noticed me. I wrote down any disturbance I heard; some examples were wallabies hopping around, or an airplane passing over. I wrote down the type of disturbance, the time it occurred, and how the koala reacted, if it reacted at all. Reactions included anything from the koala opening its eyes to moving to another tree. If the koala moved to another tree during observation and was still visible, I found another suitable spot to continue observing it. There were 19 observations total. On average, my observations took place in 6-8 hour time periods.

Travel to and from the sites and observations proved to have hazards I would have never expected while I was in America. While travelling to St. Bee's Island daily, we had to wade from the boat into shore. On this walk through the water I encountered sting rays, stonefish, and cone shells, all of which can do significant harm to people. I remember shuffling my feet as I walked to alert the sting rays, and often looking down to see one swimming away right in front of me. While on St. Bee's Island, I often encountered green ants, whose bite was unforgettable to say the least. Sometimes I'd be walking down a steep incline, slip, then grab a branch for support only to discover the branch was crawling with green ants. Between them and the spiders, I'd have an array of bites on my body by the end of the day. While observing at Mount Byron, there was certainly less encounters with wild animals, as the terrain was developed. However, during one of my observations I had a close encounter with an Eastern Brown Snake when I was sitting in the grass, which could have been deadly.

Results

I compared disturbance rates between the disturbed and undisturbed areas using an unpaired t-test. I used a logistic regression to model the probability that a koala would respond to a noise disturbance as a function of the study area, the disturbance type, and an interaction between study area and disturbance type. Included a random effect for koala ID.

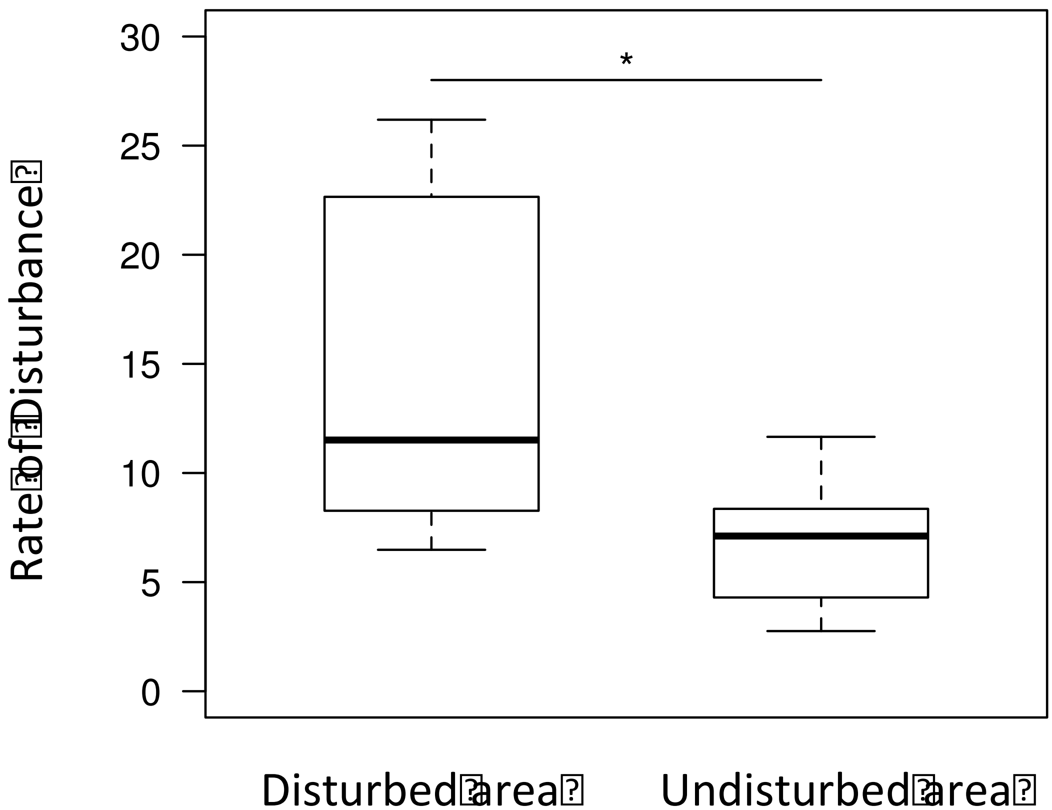

Figure 6: Wilcoxon rank sum test showing disturbance rate in the disturbed versus undisturbed area (W = 75, p = 0.013). Noise disturbance rates in the disturbed and undisturbed areas. The rate in the disturbed area was significantly higher than the rate in the undisturbed area (p=0.013). Both human and natural disturbances were included.

This figure was created in order to confirm the fact that the area that was designated as disturbed actually did have a higher rate of disturbance. The labels "disturbed" and "undisturbed" were given to these two sites based off of general observations, but graphing the rates of disturbance shows quantitative evidence that one site is significantly more disturbed.

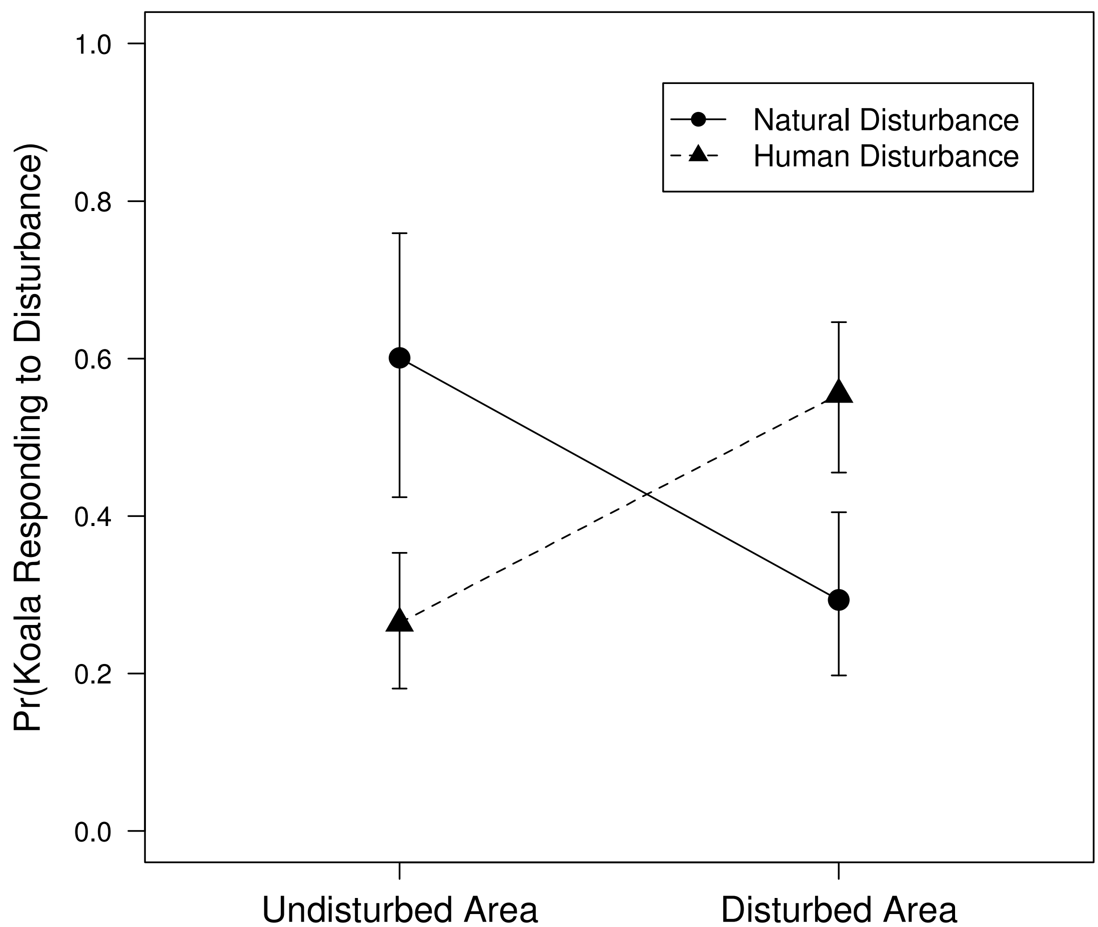

Figure 7: Mean estimates of the probability that a koala would respond to two types of noise disturbance in each of the two study areas. Mean estimates are presented with 95%

confidence intervals. The model sampled 891 observations from 19 individual koalas. The random effect of koala ID had a variance of 0.202.

This figure supported my hypothesis in that koalas are more likely to respond to human disturbances in the disturbed area. However, it also showed that koalas are more likely to respond to natural disturbances in the undisturbed compared to the probability of response in the disturbed area, which was unexpected.

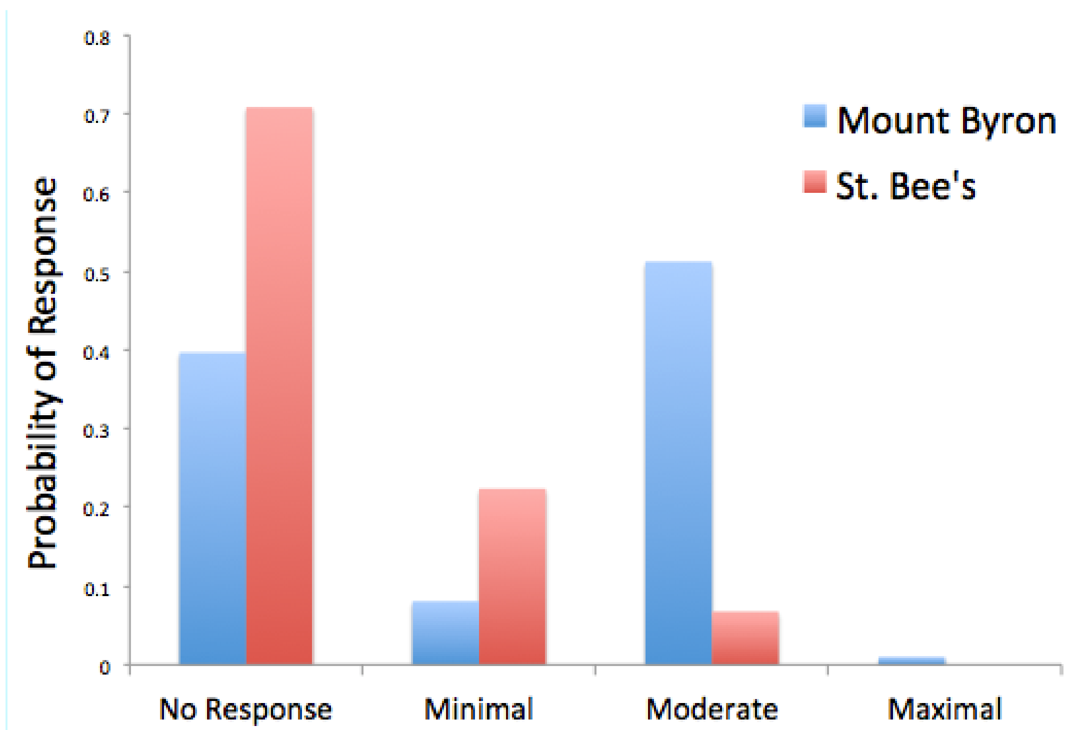

Figure 8: Levels of response contrasted by area. Minimal response included reactions such as ear twitches or the koala opening its eyes. Moderate response included the koala moving, but staying in place. Maximal response included the koala moving to a different branch or tree, or vocalizing.

This figure demonstrated that koalas responded more severely to disturbances in the disturbed area, Mount Byron. There was a higher probability of a moderate response in the disturbed area, and maximal responses were only seen in this area as well. This exhibits that a koala's behavior is more dramatically altered by disturbance in the disturbed area.

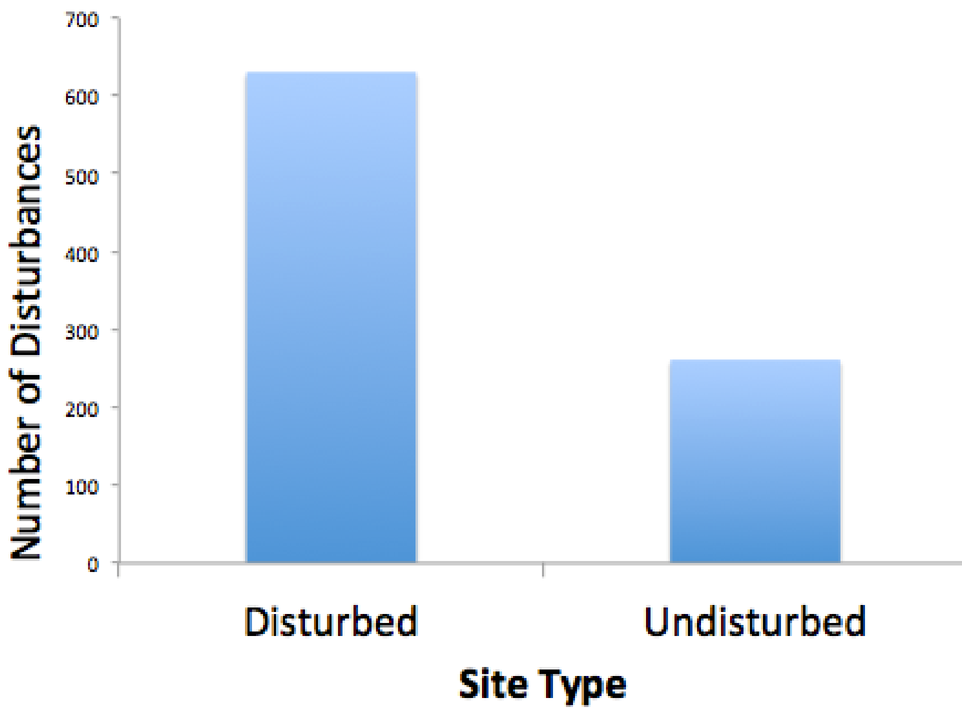

Figure 9: Total number of disturbances across the sites.

This figure shows the total number of disturbances across both areas, rather than the rate of disturbance. It is clear that there were more disturbances in the disturbed area, so its designation is accurate.

Looking at the differences between the two sites with wild koalas, there was a large difference in the amount of response to disturbances. For human disturbances at Mount Byron, which included things such as vehicle and airplane noise, the koalas responded 59.6% of the time. In contrast, koalas at St. Bee's Island only responded to human disturbances (which included things like researchers moving in the grass and boat engine noise) 29.4% of the time. The average number of disturbances that occurred per day was 78.8 at Mount Byron and 23.5 at St. Bee's Island.

Discussion

The methods used were somewhat similar to my mentor, Dr. Melzer's previous studies. For example, radio tracking was used as the method to find koalas in Ellis *et al.* 2009. They also used the same study sites as I did: St. Bee's Island and Mount Byron. My study and Melzer *et al.* 2011 both used direct observations of koalas in order to gather data. In this study, the direct observations were used to identify tree use and feeding activity, and the observation periods were 24 hours long. In both my study and the study of bottlenose dolphins in New Zealand (Constantine 2004), it was found that an increase in human presence leads to a decrease in sleep, due to the animal's attention on the human disturbance.

Figure 6 shows that Mount Byron did in fact have more disturbances than St. Bee's Island. Since Mount Byron did in fact have a higher rate of disturbance than St. Bee's, it could be stated with confidence that it was, in fact, the disturbed location. This data in itself presented some issues but also some positive news. Mount Byron is a rural area. Though it is primarily agricultural, there is protected national park land close to the site where we were observing (within a mile). The disturbances recorded included ones that could easily be heard in the national park area if we were hearing them, which means they could be affecting animals in the protected area as well as the ones who were not. On the other hand, the fact that St. Bee's had a lower rate of disturbance showed that the national park protection is working. However, this could be biased by the fact that it is an island. This data could show that protecting islands as national parks can be crucial for wildlife, as it is more difficult to have a human impact on these areas if they are isolated.

Figure 7 showed a very interesting result. It showed that in a disturbed area, a koala is much more likely to respond to a human disturbance than in the undisturbed area, which supported my initial hypothesis. However, it also showed that in the undisturbed area, a koala is more likely to respond to a natural disturbance than in the disturbed area, which was unexpected. This could be due to the fact that koalas are sensitized to natural disturbances in the undisturbed area, because that is what they are primarily exposed to, and natural predators are what pose a threat. In contrast, they may be more sensitized to human disturbance in the disturbed area because that is what is more prevalent and poses a threat to them.

Stress and Disease

This data demonstrated that in a less disturbed environment, koalas are less likely to react when a disturbance does occur. This correlates with lower stress levels (Flint and Melzer 2013). This is key in understanding their population dynamics, because increased stress levels means a suppressed immune system, making the animal more susceptible to Chlamydia, one of the main causes of mortality in the koala disease (Flint and Melzer 2013).

In a study of two free-ranging koala populations, the prevalence of two strains, *Chlamydia pecorum* and *Chlamydia pneumoniae* was studied. In an area that had sparse forest cover and cattle grazing pasture had a very high overall level of chlamydial infection (85%) with significantly more of these infections being due to *C. pecorum* (73%) compared to *C. pneumoniae* (24%). The other population, which was densely forested, had a much lower prevalence of infection (10%) with equal levels of both types of *Chlamydia*. It was also found that in the sparsely forested population, the prevalence of clinical infection was 17% out of the 85% infected (Jackson *et al.* 1999). This data demonstrates that koalas in more disturbed area have a higher presence of *Chlamydial* infection. It also shows that most of the time, the disease is subclinical and not easily identified.

Future Studies

If I were to be able to return to Australia or recommend a study to another researcher, it would be to survey the two study sites I used for the prevalence of *Chalmydia.* This data would help to determine the impact of noise pollution and human disturbance on koala health. I would also suggest a larger sample size if my study were to be repeated.

Management Implications

Efforts to conserve koala populations living near human development should consider noise pollution. Though audible human disturbance is normally not considered as highly as something like chemical pollution, it is clear that it affects koala behavior, and so should be minimized. This should especially be considered in national park areas adjacent to urban development.

Habitat fragmentation should be taken as seriously as habitat loss in terms of its effect on the behavior of a species and its survival. It is a common thought that sparse forest in farmland is better than suburban development, but this is not necessarily so. Any loss of connectivity in a habitat impedes the movement of koalas, putting them at risk for domestic dog attacks and vehicle collisions. It also creates isolated populations, which leads to a decrease in genetic diversity. This in turn can lead to inbreeding and genetic drift, which are detrimental to the survival of a population (Wilmer *et al.* 1993).

Koalas should be given a status higher than "vulnerable" on the International Union for the Conservation of Nature (IUCN) Red List in order to encourage policymakers take this conservation problem more seriously. Koalas are only listed as vulnerable because some of the existing populations are maintaining themselves. However, this designation did not take the extinct or declining koala populations into consideration, in order to make it seem as if koala populations are in good shape everywhere. Endangered is a strong word, and it may influence policy changes and the creation of more protected areas for koalas. It could also increase funding to koala research, which could help us to understand the species better.

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